Urban Solid Waste Management:

Waste Reduction in Developing Nations

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by

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Introduction

The management of solid waste is one of the challenges facing any urban area in the world. An aggregation of human settlements has the potential to produce a large amount of solid waste; the collection, transfer and disposal of that waste has been generally assumed by municipal governments in the developed world. The format varies, however in most urban areas garbage is collected either by a government agency or private contractor, and this constitutes a basic and expected government function in the developed world. Municipal solid waste (MSW) management has become a major issue of concern for many under-developed nations, however, especially as populations increase. The problem is compounded as many nations continue to urbanize rapidly; 30-50% of populations in many developing countries is urban (Thomas-Hope 1998) and in many African countries the growth rate of urban areas exceeds 4% (Senkoro 2003). Although developing nations do spend between 20 and 40% of municipal revenues on waste management (Thomas-Hope 1998, Schübeler 1996, Bartone 2000), this is often unable to keep pace with the scope of the problem. In fact, when the governments of African countries were asked by the World Health Organization to prioritize their environmental health concerns, the results revealed that while solid waste was identified as the second most important problem (after water quality), less than 30% of urban populations have access to "proper and regular garbage removal" (Senkoro 2003).

Solid waste is broadly defined as including non-hazardous industrial, commercial and domestic refuse including household organic trash, street sweepings, hospital and institutional garbage, and construction wastes; generally sludge and human waste are regarded as a liquid waste problem outside the scope of MSW. Schübeler (1996) points out that although certain contaminated medical wastes and hazardous industrial wastes are not included by definition, in many nations these are in fact part of the municipal waste stream and "special measures" must be employed to encourage their separation and mitigate their potential harmful effects. Also, the threat of toxic waste being present in industrial garbage often leads to it being treated separately, although this is not always the case.

The overall problem of MSW is obviously multi-faceted; many organizations, including the United Nations (UN) and various non-governmental organizations (NGOs) advocate an integrated approach to MSW management by identifying key stakeholders, identifying specific issues which comprise important "stumbling blocks", and making recommendations based on appropriate technologies, local information, and pressing human and environmental health concerns (UNEP 1996, Senkoro 2003, Thomas-Hope 1998). Within each sector there are various sub-sectors which can and are being dealt with separately by many nations and municipalities, for example the treatment and disposal of potentially dangerous medical wastes by urban health centers.

Current Situation

Developing countries have solid waste management problems different than those found in fully industrialized countries; indeed, the very composition of their waste is different than that of 'developed' nations. Although low-income countries' solid waste generation rates average only 0.4 to 0.6 kg/person/day, as opposed to 0.7 to 1.8 kg/person/day in fully industrialized countries, Cointreau (1982) and others (Blight and Mbande 1996, Arlosoroff 1982) noted several common differences in the composition of solid waste in developing nations:

- Waste density 2-3 times greater than industrialized nations,
- Moisture content 2-3 times greater,
- Large amount of organic waste (vegetable matter, etc.),
- Large quantities of dust, dirt (street sweepings, etc)
- Smaller particle size on average than in industrialized nations.

These differences from industrialized nations must be recognized both in terms of the additional problems they present as well as the potential opportunities which arise from their waste composition.

Before one can examine individual problems in MSW management, it is important to understand the political and economic framework in which governments must frequently work in developing countries. As mentioned above, current figures indicate that some municipal governments spend up to 50% of their revenues on waste-related issues. With

increased urbanization, demand for services will undoubtedly increase. Municipal tax and fee revenues, however, are not likely to rise as quickly as the population. This is due to the fact that of the people moving to the city, the majority are likely to be poor migrants from rural areas in search of employment, unable to contribute significantly to the revenues of the municipality. Although they may demand marginally less services due to their lower level of consumption, they are likely (at least at first) to congregate in the poorer, more densely settled areas, exacerbating the health and sanitation problems posed by these often unplanned communities.

Meeting the financial demands of MSW management will continue to be a problem in the cities of developing countries. In areas where residents are assessed fees for waste removal, the rate of collection can be quite poor (Schübeler 1996). Further, fewer and fewer people will be willing to pay in the face of poor or declining service. Many municipalities may not even be aware of the degree to which revenues are collected, or the true costs of their entire MSW operations. The problems are compounded when revenues from MSW collection are simply rolled into the general treasury, as opposed to returning to waste-related operations. Many municipalities have turned to privatization as a potential solution; certainly the financial picture is cleared somewhat when the entire system is turned over to outside contractors. However, local governments will still be held to account if service declines.

Collection and transport

Transport of waste from households, factories, and other generation sites is a growing problem. The rapid urbanization of much of the developing world leaves little time for adequate layout and planning; many of the most rapidly growing parts of cities are at the periphery of existing settlement. Garbage dumps, with their associated disease, odor and frequent fires (in some cases) would ideally be located on suitable land away from the most densely populated areas. These areas are becoming harder to find as population urbanize and municipal traffic increases; the transport of waste becomes longer and more time-consuming, and therefore more expensive and less efficient. Many cities employ neighborhood-level collection points, where households are responsible for transport to

the transfer point and the municipal or private enterprise transports the waste from there to the ultimate disposal location. Transport also relies on operational vehicles, and frequent breakdowns coupled with parts shortages can immobilize collection vehicles for extended periods of time. UNEP (1996) estimates that in cities in West Africa, up to 70% of collection/transfer vehicles may be out of action at any one time.

In areas where there exist collection services which remove waste from individual households or streets, often there are no standardized containers used to store waste prior to pickup. Headley (1998) states that in Barbados, there are no containers designated by municipalities or collection companies to "set out" waste for collection; it is up to individual residences to designate some sort of collection container. Frequently, these are plastic barrels or discarded oil drums, however the majority of households simply place grocery bags full of waste on the street to await collection. There may be physical dangers to waste workers in dealing with the former; weather, animals, and other disturbances prior to collection threaten the integrity of the latter. In an examination of current problems in Kenya, Mungai (1998) agreed that the first step in "sanitary and efficient" waste management must be to ensure that all households use some form of corrosion-resistant container with lids in order to facilitate collection. Lidded containers would exclude most animal pests, reduce the amount of rainfall soaking into garbage and help to reduce trash blowing about on the street.

A major problem is that of development at or on top of landfills; many shantytowns are built from disposed-of waste and in some cases entire neighborhoods are sited on top of existing landfills. For example, the Smoky Mountain dump in Manila, Philippines had as many as 10,000 families living in shacks on or adjacent to the dump site (UNEP 1996). Aside from the obvious health implications, these concentrations of people further complicate transport and unloading procedures and present numerous safety and logistical concerns (Blight and Mbande 1996). UNEP estimates that approximately 100,000 people currently scavenge wastes at dump sites in the Latin American region alone. Further, many people, not only those residing near landfills, make their living from scavenging on solid waste before it enters the municipal waste stream. Street-level waste

picking often removes recyclables and other 'high-value' waste items from items set out for collection; although these practices serve to reduce the overall quantity entering the waste stream, these practices often scatter waste about, compounding problems for pick-up and transfer operators (Pfammatter and Schertenleib 1996). Although it takes only 5-10 seconds to empty a 45-gallon container of waste into a collection truck, but 1-2 minutes to shovel the equivalent amount of waste (Gage 1998). Any potential change to the waste disposal framework must take into account the urban poor, many of whom may be dependent on waste scavenging for their entire subsistence. In one study at the Bisasar Road landfill in Durban, South Africa, scavenging on waste supported 200 families, "earning" the equivalent of $15,500 per month, or $77 per family per month (Johannessen 1999).

A higher solid waste density also has many implications for the 'traditional' methods of collection and disposal; collection and transfer trucks which are able to achieve compression rates of up to 4:1 in industrialized nations may achieve only 1.5:1 in developing countries, and landfill compression technology which averages volume reduction of up to 6:1 in industrial nations may only achieve 2:1 compaction with these increased waste densities (Cointreau 1982). Compactor trucks would therefore probably not be useful in many applications; as income level increases and the amount of post-consumer waste such as packaging increases correspondingly, such technologies may be more appropriate. Additionally, the high moisture content and organic composition of wastes in the developing world may lead to problems of increased decomposition rates in areas with high average daily temperatures; high seasonal or year-round rainfall would only compound these problems, presenting additional challenges with insect populations and conditions conducive to disease. To mitigate these problems, much more frequent collection is needed in hot, humid areas to remove organic wastes before they are able to decompose than would be needed in cooler, drier climates. Although daily collection has proven unreliable or unworkable in many cities (Cointreau 1982), perhaps a twice-weekly collection of organic material (possibly in conjunction with a municipal composting operation), would be sufficient to reduce decomposition.

Human health risks

There are some human health risks associated with solid waste handling and disposal in all countries to some degree, but certain problems are more acute and widespread in underdeveloped nations. Cointreau (1982) has classified these into four main categories: 1) presence of human fecal matter, 2) presence of potentially hazardous industrial waste, 3) the decomposition of solids into constituent chemicals which contaminate air and water systems, and 4) the air pollution caused by consistently burning dumps and methane release.

Human fecal matter is present in every solid waste system; in developing nations the problem varies with the prevalence of adequate sanitary disposal systems such as municipal sewerage or on-site septic systems, outhouses, etc. In areas where such facilities are lacking (especially shantytowns and over-crowded municipal districts), the amount of human fecal matter present in the solid waste stream is likely to be higher. This presents a potential health problem not only to waste workers, but also to scavengers, other users of the same municipal drop-off point, and even small children who like to play in or around waste containers. The usual disease pathways include placing contaminated hands in the mouth or eating food, through vector insects such as cockroaches or mosquitoes, or by directly inhaling airborne dust particles contaminated with pollutants. Survival time for pathogens varies with the requirements of the organism and the media in which they find themselves. In one study conducted in Indian landfills, roundworms (*Ascaris* spp.) and whipworm (*Trichuris* spp.) were commonly found, especially in those landfills located near lower-income neighborhoods and slums (Cointreau 1982).

Industrial waste can pose significant health risks for those involved in the collection and ultimate disposal of solid waste. The presence of toxic compounds in municipal solid waste is highly regulated in modern developed nations, where special procedures must be followed to ensure minimum environmental contamination and human exposure.

Environmental issues

The decomposition of waste into constituent chemicals is a common source of local environmental pollution. This problem is especially acute in developing nations; very few existing landfills in the world's poorest countries would meet environmental standards accepted in industrialized nations, and with limited budgets there are likely to be few sites rigorously evaluated prior to use in the future. The problem is again compounded by the issues associated with rapid urbanization. As land becomes scarce, human settlements encroach upon landfill space, and local governments in some cases encourage new development directly on top of operating or recently closed landfills.

A major environmental concern is gas release by decomposing garbage. Methane is a by-product of the anaerobic respiration of bacteria, and these bacteria thrive in landfills with high amounts of moisture. Methane concentrations can reach up to 50% of the composition of landfill gas at maximum anaerobic decomposition (Cointreau-Levine, 1996). In well designed and well-sited landfills there is the potential for methane recovery; few landfills in the developing world are designed to capture and make use of methane; in all of Latin America and the Caribbean, only three such landfills were in operation, all in Chile (UNEP 1996). Generally the required capital for methane recovery installations is lacking, and the low price of commercially produced gas does not make methane recovery an economically viable enterprise. In the absence of proper methane venting and/or flaring, the gas seeps into porous soil surrounding the waste and eventually migrates into basements and homes, posing an explosion risk. Carbon dioxide is a second predominant gas emitted by landfills; although less reactive, buildup in nearby homes could be a cause of asphyxiation.

A second problem with these gasses is their contribution to the so-called greenhouse gasses (GHGs) which are blamed for global warming. Both gases are major constituents of the world's problem GHGs; however while carbon dioxide is readily absorbed for use in photosynthesis; methane is less easily broken down, and is considered 20 times more potent as a GHG (Johannessen 1999). Hoornweg, et al (1999) state that for every metric ton of unsorted municipal solid waste (containing 0.3 Mt carbon), 0.2 Mt are converted to

landfill gasses. Of this gas, carbon dioxide and methane each comprise .09 Mt. Since it is believed that landfill gasses supply 50% of human-caused methane emissions and 2-4% of all worldwide greenhouse gasses (Johannessen 1999), this is clearly an area of concern in global environmental issues.

Liquid leachate management varies throughout the landfills of the developing world. Leachate poses a threat to local surface and ground water systems, and is carefully managed in developed nations. The use of dense clay deposits at the bottom of waste pits, coupled with plastic sheeting-type liners to prevent infiltration into the surrounding soil, is generally regarded as the optimum strategy to contain excess liquid. In this way, waste is encouraged to evaporate rather than infiltrate. The need for such measures depends largely on climatic conditions, as arid areas with high rates of evapotranspiration will not have nearly the potential for leachate problems as areas with high rainfall or snowmelt. Current practices in the developing world range from absolutely no leachate management (unofficial dumps or those operating continuously for years without 'sanitary' specifications) to discharge into municipal sewer and sewage systems, direct discharge into surface water systems (rivers), multi-pond aeration and settlement systems, chemical treatment facilities, and recirculation systems (Johannessen 1999).

Strategies

Given the large number of individual issues and specific problems in various municipal solid waste management systems, it would seem tempting to address individual issues as they arise and apply local fixes, so as to keep collection and disposal services operating continuously as efficiently as possible. Indeed, in the short term, this is likely to be a good approach. In considering the long term, however, it is apparent from the scope of problems and the external factors brought to bear upon municipalities that a broader, more integrated set of solutions will be necessary in order to adequately address MSW systems in the future.

Integrated approach

An integrated approach to waste management will have to take into account community- and regional-specific issues and needs and formulate an integrated and appropriate set of solutions unique to each context (Senkoro 2003, Schübeler 1996, UNEP 1996, de Klundert et al 2001). As with any issue in developing nations, solutions which work for some countries or areas will be inappropriate for others. Specific environmental conditions will dictate the appropriateness of various technologies, and the level of industrialization and technical knowledge present in various countries and cities will constrain solutions. Studies on MSW issues however repeatedly discuss certain approaches as being at least adaptable to many developing nation scenarios. These approaches emphasize waste reduction (creation of less waste and increased material recovery) and appropriate disposal options as part of an integrated evaluation of needs and conditions.

UNEP (1996) laid out a series of questions to be asked when evaluating technologies and policies in the context of an integrated MSW system:

- Is the proposed technology likely to accomplish its goals *given the financial and human resources* available?
- What option is the most *cost-effective* in financial terms?
- What are the *environmental costs and benefits*?
- Is the project feasible given *administrative capabilities*?
- Is the practice appropriate in the current *social and cultural environment*?
- What sectors of society are likely to be impacted and in what way; are these impacts consistent with *overall societal goals*?

The answer to each question may not always be immediately evident, but the process of researching and evaluating these criteria will lend insight to the appropriateness of specific solutions to the situation as a whole.

Waste reduction

It would seem that the easiest and most effective way to reduce the amount of waste to be disposed of would be to simply produce less in the first place. This is a strategy that

seems simple in concept and has shown promise; however the amount of waste produced, even in developed countries, is often a function of culture and affluence. The United States, even more so than its European or Asian counterparts, has been labeled a "throw away society", where increases in health and convenience associated with consumer goods has resulted in an increase in packaging (more items are individually packaged), resulting in significant increases in MSW as production becomes cheaper. An emphasis on mass production and the development of cheap consumer goods has caused quality and longevity of goods to be sacrificed in the name of lowest market price, causing people to be more likely to simply throw away and replace items instead of repairing or maintaining them.

The movement toward a "throw-away" has been mirrored in the developing world, especially in more affluent urban areas. In examinations of refuse generation in the USA, India, and South Africa, Blight and Mbande (1996) found that affluent communities generate 3 to 5 times as much waste as poor communities. This is not surprising since not only do poor communities have less disposable income to spend on anything aside from necessities, they also are much more ingenious in reusing and recycling materials, preventing much of their waste from ever entering the disposal stream. This of course has a positive effect on the MSW situation, however it is important to realize that as nations become more industrialized and their per capita income rises, they are likely to generate more waste per person, not less. More importantly, the availability of mass-produced items will reduce markets for used materials and goods, reducing an important incentive.

At the national level, there are several methods which can be employed to reduce the production of waste. These include redesign of packaging, encouraging the use of minimal disposable material necessary to achieve the desired level of safety and convenience; increasing consumer awareness of waste reduction issues; and the promotion of producer responsibility for post-consumer wastes (UNEP 1996). These goals may be achieved through a variety of measures, including legislative action and the creation of market forces and economic incentives which would drive these reforms forward; applicability of each goal and method would depend on circumstances present in

each situation. National reduction strategies such as these may not be relevant to the poorest of countries at present, but as these nations develop over time and their per-capita income rises (and the expected increase in post-consumer waste occurs), these measures would have more effect.

Recycling

On the local or regional level, waste reduction can be accomplished through the increased use of source separation and subsequent material recovery and recycling. Separating waste materials at the household level occurs to some extent almost universally, and prevents the most valuable and reusable materials from being discarded. Following in-home retention of valuable material, waste-pickers currently remove most valuable materials either before garbage enters the waste stream or en route, especially in the lower and middle income areas of many municipalities. In these instances, there is little need for additional encouragement of recycling. Even in the more affluent areas of developing cities, often there are found itinerant "buyers" of waste materials such as cardboard and glass. These buyers will help to divert many materials out of the waste stream, and illustrate a key point. If recycling materials is an economically viable undertaking, small enterprises have been and will continue to spring up whenever there is an opportunity; in fact the theft of source-separated recyclable materials has been documented in many pilot schemes in both developed and developing nations (UNEP 1996). Municipalities should not only recognize the trade in recyclables, it should embrace it. By allowing small enterprise to address the problem, valuable funds are saved (the municipality does not have to create a formal recycling program for most materials), jobs are created, and landfill space is saved. Perhaps through micro-loans or some small-scale assistance, local governments could support and legitimize these entrepreneurs.

Some improvement in these traditional systems is clearly desirable, however. Foremost are worker health concerns. Waste pickers are highly susceptible to disease, and it has been proposed to provide low-cost or free protective gear, such as gloves, boots, and clothing, to prevent contact injuries and reduce pathogens. Experience in Calcutta, India however has shown that most gear is simply sold by the workers for cash, and they

continued to work as before (UNEP 1996). Provision of basic health care, especially immunizations, seems a more promising route.

In areas with a large amount of waste picking, recycling of certain post-consumer wastes (on a municipally-sponsored level) is not necessarily a viable enterprise in the poorest of urban areas, at least until a raised standard of living is reached. In areas where recycling and waste diversion is not as spontaneous, municipally sponsored separation and collection may be needed. To be effective, policies need to be implemented on both the national and local levels. For example, national legislation could be employed to require manufacturers to include recycling codes (similar to the plastic coding in the US) on containers. Also, consumer education, or the incorporation of MSW issues in school curriculum, would be highly desirable. Locally, some infrastructure is required, including designated drop-off centers (in the absence of curbside collection), taking care to ensure these are conveniently located to encourage compliance. Once materials are collected, of course, some processing facilities would be required to return the collected materials to a usable form. For small nations, it may not be economically justifiable to spend the money required to erect plants capable of processing recycled material. Again, private enterprise could play a vital role in this area, provided sufficient material is collected and markets for the material exist. International trading of recyclables should be explored, to the extent nearby markets are identified. Caution should be taken, though to insure the cleanliness and integrity of collected recyclables. The deliberate or accidental inclusion of toxic materials in exported shipments of mixed materials has been documented, and represents a potential threat to shipping contracts (UNEP).

Composting

A somewhat more low-technology approach to waste reduction is composting. The waste of many developing nations would theoretically be ideal for reduction through composting, having a much higher composition of organic material than industrialized countries (table 1). In developing countries, the average city's municipal waste stream is over 50% organic material (Hoornweg, et al 1999); studies in Bandung, Indonesia and Colombo, Sri Lanka have found residential waste composed of 78% and 81%

compostable material, and market waste 89% and 90% compostable, respectively (Cointreau 1982). Still, composting has not been overwhelmingly successful and widespread in practice throughout the developing world. Although well documented in China and other areas of eastern Asia, composting projects have had a spotty record throughout Africa, Latin America and elsewhere, and have had the largest number of failed facilities worldwide (UNEP 1996). There are several reasons for this, and past history should provide a guide for its implementation in the future.

Table 1. Waste composition of selected cities (by percentage of weight) in industrialized, middle income, and low income countries (from Cointreau 1982).

	Industrialized		Middle Income		Low Income		
Waste material	Brooklyn NY	London, England	Medellin, Colombia	Lagos, Nigeria	Jakarta, Indonesia	Karachi, Pakistan	Lucknow, India
Paper	35	37	22	14	2	<1	2
Glass	9	8	2	3	<1	<1	6
Metals	13	8	1	4	4	<1	3
Plastics	10	2	5	-	3	-	4
Leather, rubber	-	-	-	-	-	<1	-
Textiles	4	2	4	-	1	1	3
Wood, bones, straw	4	-	-	-	4	1	<1
Non-food total	**74**	**57**	**34**	**21**	**15**	**4**	**18**
Vegetative (putrescible)	22	28	56	60	82	56	80
Miscellaneous inert	4	15	10	19	3	40	2
Compostable Total	**26**	**43**	**66**	**79**	**85**	**96**	**82**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

There are many advantages to composting. First and foremost, it would reduce, in some cases significantly, the amount of waste requiring ultimate disposal, extending the life of landfills. When done correctly, the end result becomes a useful product, capable of being used at the household or farm level to augment soil nutrient levels and increase organic matter in the soil, increasing soil stability. If the product is of high enough quality and markets exist, the product can be sold. Environmentally, the process by which

composting decomposes organic waste is preferable to landfill processes. In a landfill, bacteria break down organics anaerobically in the absence of oxygen, resulting in the aforementioned releases of methane gas. When properly composted, however, the organic matter is decomposed using an aerobic process, which produces no methane by-product.

There are three scales at which composting has been implemented; the residential level, the decentralized community level, and the centralized large-scale (municipality-wide) level; the larger the undertaking, the more capital investment is required. Most developing countries which have found success with composting have found it works best when implemented at the household level, with some projects doing well at the community level as well. At the municipal level, certainly overall cost and functionality are the primary reasons for the success of a given process; the financial commitment required, as well as the effort required to maintain equipment sufficiently to keep a large scale operation running, has resulted in widespread failures; including India (9 of 11 plants closed between 1974 and 1996), Brazil (only 18 of 54 facilities operating in 1990), and elsewhere (Hoornweg, et al 1996).

Failures have been attributed to many reasons; among the most important are (Hoornweg, et al 1999, UNEP 1996):

- Failure to understand and maintain *biological conditions* required
- Failure to properly understand market conditions and correctly *predict demand* for finished product
- Poor *pre-sorting of incoming waste* to remove non-compostable materials resulting in poor finished product
- An over-emphasis on high-cost mechanization as opposed to *manual labor*
- Overall *higher economic costs* than those associated with landfilling same quantity of waste

Hoornweg, et al. (1996) also documented neighborhood-level composting in some areas; it has been successful in several cases. In Jakarta in 1990, a community composting project was quite successful, owing to government help (providing rent-free land to

establish the site), extensive worker and community education, and establishing a distributor for the final product long before construction began. In 1997, however, the project lost its main distributor and now the facility is only able to run at half capacity. In Brazil, some communities are able to operate medium-size community operations even where municipal projects have failed.

Household-level composting has the greatest potential for success in many areas, especially those where small scale agriculture is found in great abundance close to urban areas, or those where limited gardens are found within the city itself. The key is to find a useful destination for the final product, either by selling to neighborhood farmers/gardeners or on the household's own plots. Education is the key to promoting this type of project, since many people will have concerns regarding possible disease, odors, and pest problems. These issues rarely occur in a properly maintained compost pile; education regarding what waste should be added and how to properly construct a compost bin to eliminate rodents, etc. would overcome most concerns.

Landfills

The placement of solid waste in landfills is the probably the oldest and definitely the most prevalent form of ultimate garbage disposal. From the outset, it must be recognized that many "landfills" are nothing more than open, sometimes controlled, dumps. The difference between landfills and dumps is the level of engineering, planning, and administration involved. Open dumps are characterized by the lack of engineering measures, no leachate management, no consideration of landfill gas management, and few, if any, operational measures such as registration of users, control of the number of "tipping fronts" or compaction of waste. In an examination of landfills throughout the developing world in 1997-1998, Johannessen (1999) found varying amounts of planning and engineering in MSW dumping; among the various regions visited, African nations (with the exception of South Africa) had the fewest engineered landfills, with most nations practicing open dumping for waste disposal; waste managers in Asian and Latin American nations were more likely to be aware of environmental effects of improper

landfill design and were much more likely to design and implement some control measures, however limited in scope.

'Sanitary' landfills, on the other hand, are sites where waste is allowed to decompose into biologically and chemically inert materials in a setting isolated from the environment. Cointreau (1982) outlined four features that must be present in order for a landfill to be considered sanitary:

- *Full or partial hydrogeological isolation* through the use of liners to prevent leachate infiltration into the soil and groundwater; collection and treatment infrastructure should be used where leachate is expected to be generated
- *Formal engineering preparations* with an examination of geological and hydrological features and related environmental impact analysis, waste tipping plan and final site restoration plan
- *Permanent control*, with trained and equipped staff to supervise construction and use
- *Planned waste emplacement and covering*, with waste and soil placed in compacted layers as well as daily and final soil cover to reduce water infiltration and reduce odors and pests

Other practical and social considerations must be addressed when planning landfills, especially in the context of developing nations and their problems as outlined above. One of the most important is the siting of landfills in proximity to urban areas. Naturally, there are few people who would be excited by having a landfill in their backyard, however it is important to realize that landfills must be located within a reasonable distance to population concentrations along a good road system. If they are located too far from collection points and transfer stations, waste transport could become prohibitively expensive due to the distance the waste is transported. In the poorest of nations, development agencies may finance all or part of landfill construction. However if it is sited far from the urban area, without regard to the ability of the government to transport waste with its limited finances, scattered unregulated dumping will become financially attractive once again.

It is obvious that a proper, engineered landfill is more expensive to design, implement and maintain. This is naturally the main constraint in developing countries, and therefore landfill construction is a focus of development assistance by the World Bank and many other aid organizations. Although the costs may be defrayed and technical assistance given, in the long term it will be the responsibility of local and national governments to ensure proper waste disposal is a practical and viable option.

Incineration

Another option for waste reduction and disposal is incineration. Incineration should not be considered a 'disposal' option, since following incineration there is still some quantity of ash to be disposed of (probably in a landfill), as well as the dispersal of some ash and constituent chemicals into the atmosphere. It should instead be considered more in terms of its waste-reduction potential, which can be 80-95% in terms of waste volume (Rand, et al 2000). This appears to be an extremely attractive option, however, with occasional exceptions, incineration is an inappropriate technology for most low-income countries. Above all, the high financial start-up and operational capital required to implement incineration facilities is a major barrier to successful adoption in developing countries (Rand et al 2000, UNEP 1996). A large portion of that cost is the environmental hazard mitigation components, including emissions "scrubbers"; use of best available technology in the United States can cost as much as 35% of the overall project cost (Rand et al 2000). Additionally, specific technical expertise and related general repair and maintenance technology are often absent in developing nation scenarios. High costs and environmental problems have led to incinerators being shut down in many cities, among them Buenos Aires, Mexico City, Sao Paolo and New Dehli (UNEP 1996). High costs can be recouped by coupling incinerators with energy-recovery infrastructure. Generation of hot water and steam, to generate electricity or for heating applications in nearby residential and industrial sites is a possibility, and has been used in some developed world sites. The additional level of infrastructure and planning required to implement such a scheme is most likely well beyond the realm of possibility in most developing nations, and arguments for the adoption of incineration projects should not rely on potential energy generation as a primary component of the "sales pitch".

Financially and practically, incineration seems at present a promising option for few countries; however small island nations are perhaps a category where such technology may be practical. With their smaller land mass, island nations often have less land available to them for landfilling, and even in the event land is available, environmental considerations may not reveal these sites to be viable options. Further, in nations with islands scattered about, transportation of waste to select centralized sanitary landfills, instead of open dumps on each island, could be prohibitively expensive and time consuming. Being surrounded by open water increases the attractiveness of ocean dumping. Most developed nations have abandoned this practice out of environmental concerns, however environmental regulations may not outlaw this practice in some poorer nations. Reduction by incineration, along with sanitary disposal of the residue, would therefore be a useful alternative to traditional disposal methods, and have proven useful in nations such as Bermuda and the British Virgin Islands (Lettsome 1998).

There are two widely used varieties of incineration plant as described by UNEP (1996), mass-burn and modular. A third, fluidized-bed incineration is used widely in Japan. Mass-burn systems are the most versatile, accepting almost any common municipal solid waste save for large single items such as refrigerators and furniture. Waste is dumped from trucks onto either a tipping floor or a conveyor belt, which then conveys the waste to the incineration chamber. Common facilities use two or three incineration chambers, providing a capacity of between 100 and 3000 tons per day; modular incinerator units, on the other hand, can usually only process between 5 and 120 tons MSW per day per unit, although multiple units are often used at any one site. The process of incineration is somewhat different, utilizing two combustion chambers; gasses generated in the first chamber are more completely combusted in the second, providing the primary environmental pollution control.

Negative environmental consequences of incineration mostly revolve around airborne emissions. Certainly, incinerators should not be located where prevailing wind patterns would carry emissions over densely settled areas. The use of emissions reduction

technology, although expensive, should be mandatory in any new construction. Incineration volatilizes many compounds potentially harmful to human health: metals (especially lead and mercury), organics (dioxins), acid gases (sulfur dioxide and hydrogen chloride), nitrogen oxides, as well as carbon monoxide and dust (UNEP 1996).

Conclusion

Municipal solid waste issues represent major problems to the governments of developing nations. As poorer nations grow and develop, improvements in infrastructure and technology should help to overcome barriers to the safe disposal of urban waste. Environmental regulations, intelligently designed to protect the health and integrity of ecosystems and human populations, should be created and enforced now in order to prevent the need for costly remediation measures in the future.

Approaching the problem intelligently is of course no easy task. Allen Hershkowitz (2001) of the Natural Resources Defense Council described how even a nation such as Belize, which markets itself as an international ecotourism destination with deep concern for the environment, can be prone to making major decisions without proper regard for environmental consequences. In 1997, the government of Belize stated that "mismanagement of waste" was the number one environmental problem in the country. At the same time it approved a new disposal site, named Mile 27 landfill, to replace its current open dump outside Belize City. The plan for Mile 27 was filled with environmental problems. The landfill was to be in an abandoned quarry site adjacent to the Sibun River. The landfill was designed without any impermeable barriers to control leachate, despite the fact that the rock lining the quarry was mostly limestone, karst, and marl. All rather porous materials, these rocks would readily conduct leachate into the surrounding soil and ultimately into the river. Yet the environmental impact statement prepared by the Canadian developer provided for no regulation of landfill gases or leachate management, despite the fact that downstream of the dump site 12 villages use the river for drinking water and subsistence fishing. The Belize government attempted to push the project ahead and funding was secured from the Inter-American Development Bank (IADB). Only after one and a half years of pressure on the government and the

IADB from environmental NGOs and through citizen protests, was the project moved to a less controversial and environmentally more appropriate site.

This story illustrates a major problem. Although funding for major MSW projects often comes from developed nations and international organizations, they often ignore the major environmental side effects of large-scale projects, and even the needs and concerns of local citizens. Large development projects are pushed forward "from the top down", without hearing the concerns of those who will be most affected. For solutions to be environmentally and economically sustainable, priorities need to be adjusted to give appropriate weight to the needs of all stakeholders in developing countries, including governments, affected landowners, and the rural and urban poor. Adopting an integrated approach using appropriate technology is a major component to ensuring that municipal solid waste problems are addressed in a manner which provides for the greatest common benefit.

References

Arlosoroff, Saul 1982. "WB/UNDP Integrated resource recovery project: Recycling of wastes in developing countries." In: *Appropriate Waste Management for Developing Countries,* edited by Kriton Curi. New York: Plenum Press, 1985

Bartone, C. 2000. *Strategies for Improving Municipal Solid Waste Management: Lessons from World Bank Lending and CWG Activities*. Workshop on Planning for Sustainable and Integrated Solid Waste Management, Manila, 18-22 September 2000. Washington, DC: Urban Management Division, World Bank.

Blight, G.E. and Mbande, C.M. 1996. *Some problems of waste management in developing countries*. Journal of Solid Waste Technology and Management 23, no. 1, February 1996. pp 19-27.

Cointreau, S. 1982. *Environmental Management of Urban Solid Wastes in Developing Countries: A Project Guide*. Washington, DC: Urban Development Department, World Bank.

Cointreau-Levine, S. 1996. *Sanitary landfill siting and criteria*. Washington DC: World Bank Infrastructure Notes, Urban No. UE-12.

Gage, Ian. 1998. "The effect of the method of household containment on solid waste management." In: *Solid waste management: critical issues for developing countries*, edited by Elizabeth Thomas-Hope, 159-167. Kingston: Canoe Press.

Headley, Jeffrey 1998. "An overview of solid waste management in Barbados." In: *Solid waste management: critical issues for developing countries*, edited by Elizabeth Thomas-Hope, 159-167. Kingston: Canoe Press, 1998.

Hershkowitz, Allen. 2001. *Dumping on paradise*. Amicus Journal 23, no. 1, Spring 2001.

Hoornweg, D., Thomas, L. and Otten, L. 1999. *Composting and Its Applicability in Developing Countries*. Urban Waste Management Working Paper Series 8. Washington, DC: World Bank.

Johannessen, L.M. 1999. *Observations of solid waste landfills in developing countries: Africa, Asia and Latin America*. Urban and Local Government Working Paper Series No. 3, The World Bank, Washington, DC.

Lettsome, C. 1998. "The environmental impact of incineration on island nations." In: *Solid waste management: critical issues for developing countries*, edited by Elizabeth Thomas-Hope, 159-167. Kingston: Canoe Press, 1998.

Mungai, G. 1998. “Solid waste management and its environmental impact in Kenya”. In: *Solid waste management: critical issues for developing countries*, edited by Elizabeth Thomas-Hope, 159-167. Kingston: Canoe Press, 1998.

Pfammatter R. and Schertenleib, R. 1996. *Non-Governmental refuse collection in low-income urban areas*. Swiss Federal Institute for Environmental Science and Technology, SANDEC report no. 1/96.

Rand, T., Haukohl, J. and Marxen, U. 2000. *Municipal Solid Waste Incineration, A Decision Maker's Guide*. Washington, DC: The International Bank for Reconstruction and Development, World Bank.

Schubeler, Peter. 1996. *Conceptual framework for municipal solid waste management in low-income countries*. United Nations Development Program, UMP Working Paper Series no. 9. St. Gallen, Switzerland: SKAT.

Senkoro, Hawa. 2003. Solid Waste Management in Africa: A WHO / AFRO Perspective. Paper 1, presented in Dar Es Salaam at the CWG Workshop, March 2003. Retrieved electronically: http://www.skat.ch/sf-web/activities/ws/cwg/pdf/cwg-01.pdf

Thomas-Hope, Elizabeth, ed.1998. *Solid waste management: critical issues for developing countries*. Kingston: Canoe Press.

UNEP. 1996. *International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management*. UNEP Technical Publication 6, Nov. 1996.

Van de Klundert, A., Anne Scheinberg, Maria Muller, Nadine Dulac and Lane Hoffman. 2001.*"Integrated Sustainable Waste Management - A Set of Five Tools for Decision-makers - Experiences from the Urban Waste Expertise Programme (1995-2001): ISWM - The Concept, Micro- and Small Enterprises, Financial and Economic Issues, Community Partnerships, The Organic Waste Flow"*. Gouda, Netherlands: WASTE 2001.